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COMPARATIVE STUDIES ON THE PERFORMANCE PARAMETERS, EXHAUST EMISSIONS AND COMBUSTION CHARACTERISTICS OF MODIFIED SI ENGINE OVER CONVENTIONAL ENGINE

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ABSTRACT

Experiments were conducted for evaluating the performance parameters, control of pollution levels and combustion characteristics of a single cylinder, air-cooled, Bajaj make, 2.2 kW BP, 3000 rpm, two-stroke, catalytic coated (copper coated on the piston crown and on the inner surface of cylinder head), methyl alcohol-gasoline blend (80% gasoline, 20% methyl alcohol, by volume) operated SI engine with a compression ratio of 7.5:1, connected to an electrical swinging field dynamometer with resistive loading for. The engine performance parameters are brake thermal efficiency (BTE), brake specific energy consumption (BSEC), exhaust gas temperature (EGT) and volumetric efficiency (VE), while, the engine exhaust emissions are carbon monoxide (CO), un-burnt hydro carbons (UBHC) and aldehydes (formaldehydes and acetaldehydes). The combustion characteristics are peak pressure (PP), time of occurrence of peak pressure (TOPP), maximum rate of pressure rise (MRPR), maximum heat release (MHR) and temperature of exhaust emissions at exhaust port opening (EPO). The performance parameters, exhaust emissions and combustion characteristics were determined at full load operation of the engine, while, BTE was determined at peak load operation. Alcohol-gasoline blend fueled copper coated combustion chamber considerably improved the performance, reduced the pollutants with sponge iron catalyst in the catalytic converter fitted to the exhaust pipe, and improved the combustion parameters over conventional engine with pure gasoline operation.

KEYWORDS: Conventional Engine, Copper Coating, Performance, Exhaust Emissions, Combustion Characteristics

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Case Study

INTRODUCTION

The increase in fuel consumption and depletion of fossil fuels necessitates the search for alternate fuels. The main objective of any engine designer is that, the engine should give maximum thermal efficiency with minimum pollution levels. To achieve this, different alternate and renewable fuels have been used in SI engines by many researchers. As alcohols have got properties similar to those of base fuel (gasoline), they are the better alternate fuels for SI engines. Engine designs are modified to improve the thermal efficiency and to minimize the pollutants. When small quantities of methyl alcohol are blended [1], [2], with the base fuel, no major engine design modification is required.

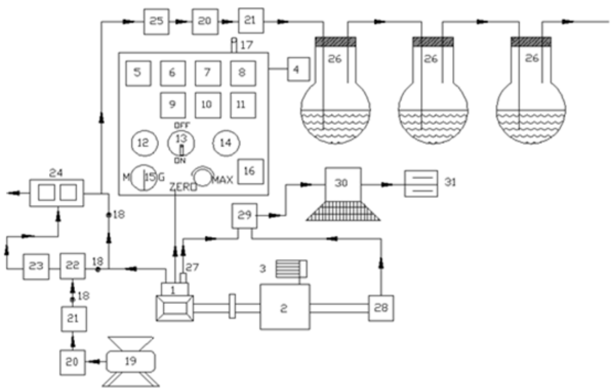
Many investigations were carried out on SI engines to improve the performance by varying spark plug timing, increasing the compression ratio and coating the engine components with high conductive material like copper. Out of these methods, copper coating was a simple technique and can easily be adopted. As copper has high

thermal conductivity, it improves preflame reactions and turbulence [3], [4], [5] in SI engines. Catalytic converters provide a simple solution to control the pollutants with abundantly available and cheap catalyst [6], [7]. Like sponge iron. The combustion characteristics were evaluated by special p-Ө software.

The present paper evaluated the performance of copper coated combustion chamber, which includes determining performance parameters at various values of brake mean effect pressure, control of exhaust emissions of CO, UBHC and aldehydes (formaldehydes and acetaldehydes), and determining combustion characteristics at full load operation, with alcohol blended gasoline (gasoline-80% and methanol- 20% by volume) and compared with CE with pure gasoline operation. Exhaust emissions of CO, UBHC and aldehydes (formaldehydes and acetaldehydes) were controlled by catalytic converter with sponge iron catalyst.

METHODOLOGY

Figure 1 shows the schematic diagram of the experimental set up that was employed to evaluate the performance parameters.



1. **Engaine, 2. Electrical swinging Field dynamomètres, 3.Loading arrangement, 4.Fuel tank, 5.Torque indicator 6. Fuel rate indicator sensor, 7. Hot wire gas flow indicator, 8. Multi- Channel température indicator, 9. Speed indicator, 10. Air flow indicator, 11. Exhaust gas température indicator, 12. Mains ON, 13. Engine ON/OFF Switch, 14. Mains OFF, 15. Motor/ Generator option Switch, 16. Heater Controller, 17. Speed indicator, 18. Directionnel valve, 19. Air compressé, 20. Rotometer, 21. Heater, 22. Air chamber, 23. Catalytic chamber, 24. CO/HC analyzer, 25. Filter, 26. Round Botton flasks containing DNPH solution, 27. Piezoelectric pressure transducer, 28. TDC encoder, 29. Consol, 30. Pentium personal computer, 31. Printer.**

Figure 1: Schematic Diagram of the Experimental Set Up

In the catalytic coated engine, a high thermal conductive catalytic material like copper was coated on the cylinder head inside surface and top surface of piston crown by METCO flame spray gun. Initially for a thickness of 100 microns thickness, a bond coating of nickel-cobalt-chromium was sprayed. On this coating, an alloy of copper (89.5%), aluminium (9.5%) and iron (1%) was coated for another 300 microns thickness. Dhandapani et al. [3] conducted experiments on copper coated SI engine with gasoline as fuel and life test was carried out for 50 hours. During these 50 hours, wear and tear was not reported from the engine.

Plate 1 shows the photographic view of copper coated piston, liner and copper coated cylinder head.

Plate 1: Photographic View of Copper Coated Piston, Liner and Copper Coated Cylinder Head

The fuel consumption, speed, torque, air flow rate and exhaust gas temperature were measured with digital electronic sensors. A pressure-feed system provides the engine oil. Temperature control was not provided while measuring the temperature of lubricating oil. The major exhaust emissions from the engine are CO, UBHC and Aldehydes. A Netel Chromatograph analyzer was used to measure CO emissions (%) and UBHC emissions (ppm). Aldehyde emissions (formaldehydes and acetaldehydes, % concentration) were measured by employing wet chemical 2,4 Dinitrophenyl hydrazine (DNPH) method [8]. The engine exhaust was bubbled through DNPH in hydrochloric acid solution to form the hydrazones which are extracted into chloroform. By employing HPLC [9], these hydrazones were analyzed to find the percentage concentration of formaldehydes and acetaldehydes.

A catalytic converter [10] (Figure 2) is fitted to exhaust pipe of engine. Provision is also made to inject a definite quantity of air into catalytic converter. Air quantity drawn from compressor and injected into converter is kept constant so that backpressure does not increase.

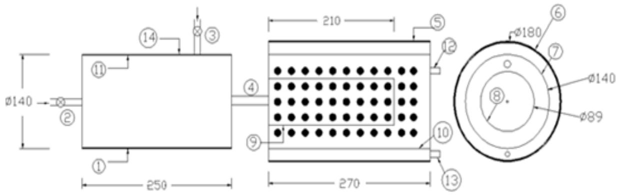


Figure 2: Details of Catalytic Converter

Note: All dimensions are in mm

1. Air chamber, 2. Inlet for air chamber from engine, 3. Inlet for air chamber from compressor, 4. Outlet for air chamber, 5.Catalytic chamber, 6. Outer cylinder, 7. Intermediate-cylinder, 8. Inner-cylinder, 9. Inner sheet, 10. Intermediate sheet, 11.Outer sheet, 12. Outlet for exhaust gases, 13. Provision to deposit the catalyst, and, 14. Insulation

The Piezo-electric pressure transducer fitted on the cylinder head to measure pressure in the combustion chamber was connected to a consol, which in turn was connected to Pentium personal computer. TDC encoder provided at the extended shaft of the dynamometer was connected to the consol to measure the crank angle of the engine. Pressure-crank angle diagram was obtained on the screen of the personal computer. A special P-θ software package evaluated the combustion characteristics.

RESULTS AND DISCUSSIONS

Figure 3 shows the variation of BTE with BMEP in CE with pure gasoline and CCE with methanol blend.

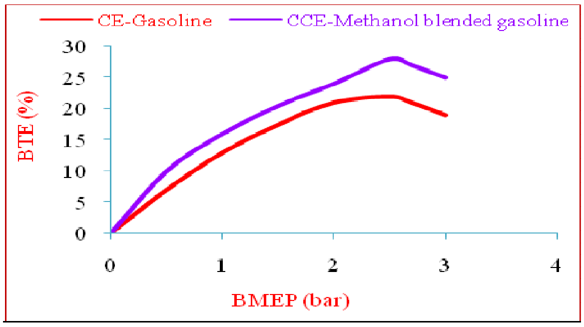


Figure 3: Variation of BTE with BMEP in CE and CCE with Test Fuels

From the Figure 3 it was observed that, BTE was higher with methyl alcohol blend in CCE over CE with pure gasoline particularly at near full load operation at all loads due to lower stoichiometric air requirement of alcohol blended gasoline over pure gasoline operation and also due to efficient combustion with catalytic activity.

Figure 4 showing the experimental values of BSEC at full load opération of CE and CCE.

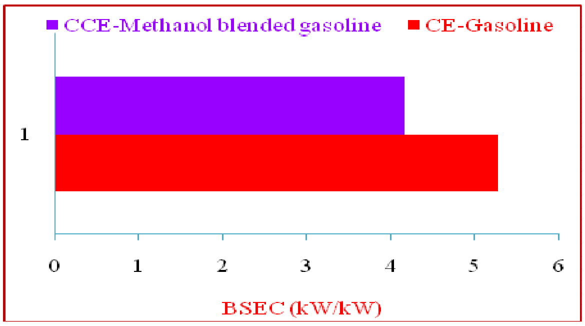


Figure 4 : Experimental values of BSEC in CE and CCE with Test Fuels

When compared with the base fuel the mass flow rate of burning of methyl alcohol was lower. Therefore methyl alcohol blend consumes less energy when compared with the base engine, as the consumption of energy depends on the consumption of mass of fuel and heating value of the fuel.

Figure 5 shows the variation of BTE with BMEP in CE with pure gasoline and CCE with methanol blend.

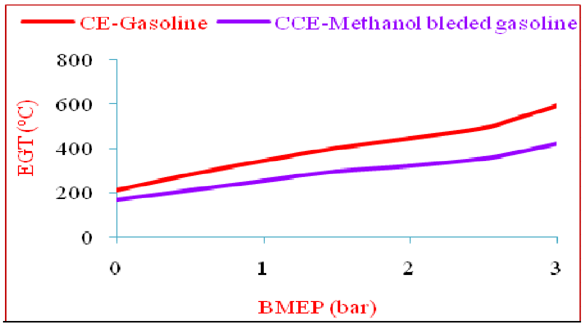


Figure 5 : Variation of EGT with BMEP in CE and CCE with test Fuels

Since methyl alcohol has high latent heat of evaporation, it absorbs more amount of heat from combustion reactions causing reduction of EGT when compared with base fuel. The heat thus produced was diverted in increasing BTE for CCE causing reduction in EGT in comparison with the base engine. Hence CCE was more suitable for alcohol blend.

Figure 6 shows the variation of VE with BMEP in CE with pure gasoline and CCE with methanol blend.

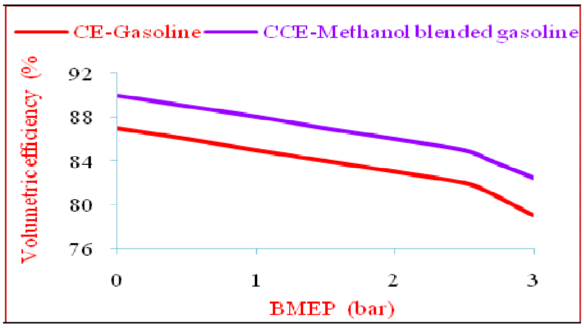


Figure 6 : Variation of VE with BMEP in CE and CCE with test Fuels

From the Figure 6, VE was observed to be higher with methyl alcohol blend in CCE over CE, due to higher latent heat of evaporation of alcohol, the decrease of fuel deposits and concentration of fuel at the walls of combustion chamber.

Figure 7 shows the variation of CO emissions with BMEP in CE and CCE with experimental fuels.

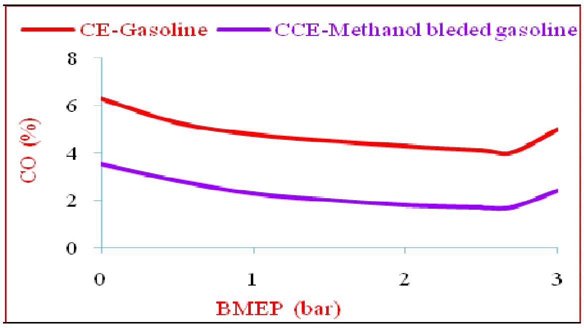


Figure 7 : Variation of CO Emissions with BMEP in CE and CCE with Test Fuels

Since more oxygen was available with methyl alcohol in its composition and also catalytic coating promotes the combustion, the formation of CO emissions was decreased. Similar trends were noticed by other researchers [3], [5] with base fuel operation on the catalytic coated engine.

Figure 8 shows the variation of UBHC emissions with BMEP in CE and CCE with test fuels.

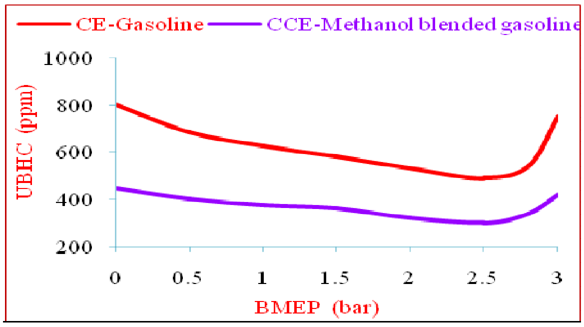


Figure 8: Variation of UBHC Emissions with BMEP in CE and CCE with Test Fuels

Because of copper coating, flame speed increases with catalytic activity and thus quenching effect decreases, which decreases UBHC emissions. The exhaust emissions can further be reduced by fitting catalytic converter to the exhaust pipe of the engine. The catalytic converter is provided with sponge iron catalyst and air injection in to it. Table 1 shows the magnitudes and the percentage (%) deviation of aldehyde emissions from methyl alcohol-gasoline blend fueled

copper coated engine with catalytic converter employing sponge iron catalyst and air injection, over that of conventional engine with pure gasoline.

Table 1 : Variation of UBHC Emissions with BMEP in CE and CCE with Test Fuels

Exhaust Emission	Conventional Engine (Base Engine with Pure Gasoline Operation)	Modified Engine (Methanol-Gasoline Blend Fueled Copper Coated Engine with Catalytic Converter, Sponge Iron Catalyst and Air Injectiom)	Percentage (%) Deviation of the Exhaust Emissions from Modified Engine Over Conventional Engine
CO émissions	5	0.96	- 80.8%
UBHC émissions	750	168	- 77.6%
Formaldehyde émissions	9.1	5.5	- 39.5%
Acetaldehyde émissions	7.7	3.1	- 59.7%

From the Table 1 it was observed that, methyl alcohol blend was more suitable in reducing the pollutants rather than the base fuel. CCE was more effective in reducing the pollutants with catalyst in comparison with CE, as improved combustion is achieved due to turbulence with copper coating. The exhaust emissions were observed to be decreased with the catalytic converter and were further decreased with the injection of air in to the catalytic converter. This was because of the completion of oxidation reaction with the catalyst which results in the formation of CO_2 instead of CO. Sponge iron catalyst was found to be more effective in the decrease of CO, UBHC and aldehyde emissions from the modified engine over conventional engine, because there is no formation of highly reactive chemical compounds due to increase of pre-flame reactions [5], [11], [12] and turbulence so that there was improved combustion.

Figure 9(a), 9(b), 9(c), 9(d) and 9(e) presents the bar charts showing the variation of PP, TOPP, MRPR, MHR and temperature of burned gases at EPO in CE with pure gasoline and CCE with alcohol blended gasoline.

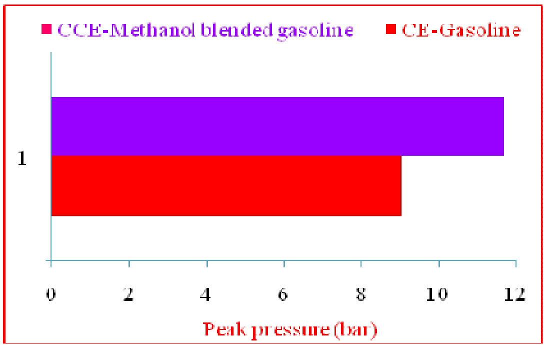


Figure 9(a :) Experimental values of PP in CE and CCE with Test Fuels

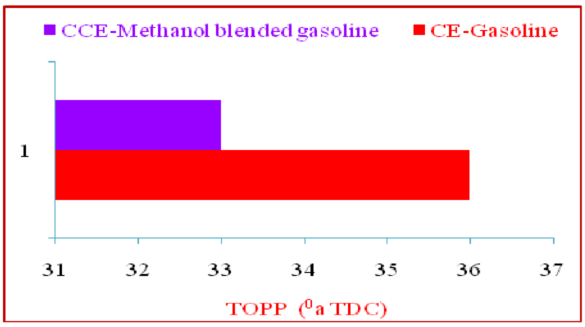


Figure 9(b) : Variation of TOPP in CE and CCE with Experimental Fuels

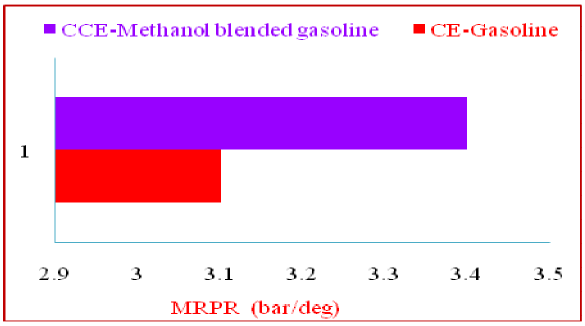


Figure 9(c :) Variation of MRPR in CE and CCE with Test Fuels

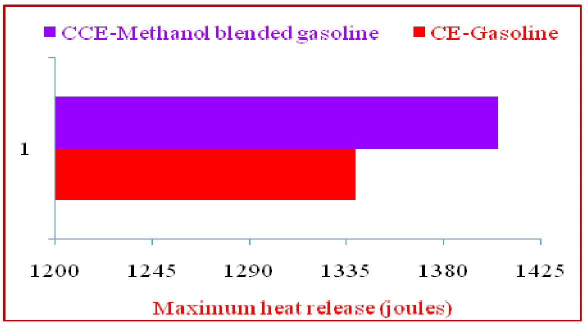


Figure 9(d) : Variation in the Values of MHR in CE and CCE with Test Fuels

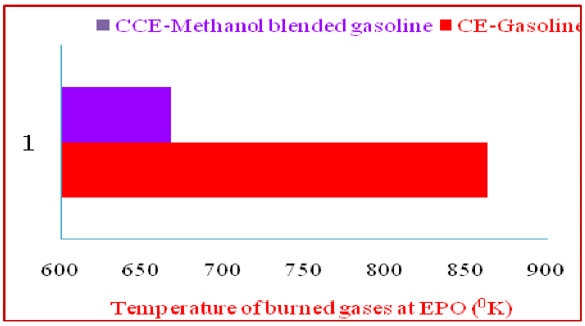


Figure 9(e :) Experimental values of Temperature of Burned Gases at EPO in CE and CCE with test Fuels

PP was found to be higher [Figure 9(a)] and TOPP was observed to be minimum [Figure 9(b)] in the catalytic coated engine with methyl alcohol blend. Addition of methyl alcohol aids the process of combustion, decreased the energy flow in to the crevices, reduction in the temperature of cylinder, decrease of the ignition delay, increase in the speed of propagation of flame front and decreased the combustion duration. It was clear from the Figure 9(c) that, MRPR followed similar trends as that of PP. MRPR was found to be within the limits from which it can be said that the engine is not in the knocking condition. Higher heat release was obtained at the point where the peak pressure is obtained. MHR was found to be more with methanol blended gasoline [Figure 9(d)] in the configuration of CCE which confirms that CCE is more suitable in achieving higher efficiency for methanol blended gasoline. From these diagrams it was understood that the temperature of burned gases at EPO is found to be minimum for methanol blended gasoline [Figure 9(e)] in CCE which confirms that CCE is more suitable in achieving higher efficiency for methanol blended gasoline.

CONCLUSIONS

- In comparison with the base engine, peak BTE increased by 27.3%, EGT at full load decreased by 195 ^{0}C and VE

at full load increased by 4.5% with methyl alcohol blend in the catalytically activated engine.

- Catalytic coated engine with methyl alcohol blend and sponge iron catalyst in the catalytic converter decreased the CO, UBHC, formaldehyde and Acetaldehyde emissions by 81% , 78%, 40% and 60% respectively with air injection in comparison with the base engine.
- Methyl alcohol blend in copper coated engine increased PP, MRPR and MHR by 30%, 10% and 5% respectively, while, TOPP and temperature of exhaust gases at EPO decreased by 8.3% and 195 K respectively when compared to the base engine operation.

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